

NOAA CoastWatch SAR Applications and Demonstration: Status and Plans

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Abstract

The goal of the National Oceanic and Atmospheric Administration (NOAA) CoastWatch Program is to provide satellite and other environmental data and products for near real-time monitoring of U.S. coastal waters in support of environmental science, management, and hazard response. During the last few years, products available through CoastWatch have expanded beyond the original infrared, visible, and sea surface temperature image products to include ocean color, scatterometer wind, and synthetic aperture radar (SAR) images. A NOAA research and development program with partners in government, academia, and industry has endeavored to develop coastal ocean SAR applications for CoastWatch. Some of these SAR applications, in particular wind measurement and hard target (i.e. vessel) detection, were developed for a preoperational demonstration in Alaska that started in the fall of 1999. Users include the NOAA National Weather Service, the Alaska Department of Fish and Game, and the U.S. Coast Guard.

Keywords: SAR, Winds, CoastWatch, Vessels

Introduction

This article describes the status and plans of a preoperational applications demonstration of coastal ocean synthetic aperture radar (SAR) imagery and products that began in the fall of 1999 in Alaska. This “Alaska SAR Demonstration” is first presented within the context of the National Oceanic and Atmospheric Administration (NOAA) CoastWatch Program. The key operational users are then introduced, followed by a description of the initial demonstration products. An outline of the data flow concludes the description of the demonstration.

CoastWatch

CoastWatch is a NOAA activity managed by the National Environmental Satellite, Data, and Information Service (NESDIS) with CoastWatch “nodes” located at NOAA laboratories and offices in eight coastal states (see Fig. 1). The core mission of CoastWatch is to provide satellite (and other environmental) data and products for near real-time monitoring of U.S. coastal waters in support of environmental science, management, and hazard response. The CoastWatch nodes receive products from NESDIS or generate them locally. These products are then made available to a diverse and growing user community of federal, state, university, secondary school, and industry environmental resource managers, research scientists, educators, students, marine enthusiasts, and commercial marine enterprises. Satellite products include polar and geostationary

satellite infrared, visible, and sea surface temperature (SST) images, as well as ocean color and synthetic aperture radar (SAR) imagery. Established in 1990, with all eight nodes operating by 1993, CoastWatch now has over 2000 registered users. CoastWatch data and products are accessible in near real-time via web sites at each node (see the CoastWatch home page at <http://coastwatch.noaa.gov>). The NOAA National Oceanographic Data Center (NODC) maintains the CoastWatch SST and polar-satellite infrared and visible image archive, providing another point of access to CoastWatch data, particularly retrospective data (see the NODC CoastWatch home page at <http://www.nodc.noaa.gov/NCASS/ncass-home.html>). Most CoastWatch products are freely available over the Internet after registration with one of the CoastWatch nodes; however, ocean color and SAR imagery have data distribution restrictions. These data can only be distributed to U.S. Government agencies and their contractors or to those agencies and researchers participating in approved research and applications demonstration projects.

SAR Applications of Interest to CoastWatch

SAR imagery from the European Space Agency's European Remote Sensing Satellites 1 and 2 (ERS-1/2) and the Canadian Space Agency's RADARSAT-1 have been used experimentally for a number of years at both the Alaska and Great Lakes CoastWatch nodes [1]. Applications of interest to CoastWatch are listed in Table 1 [2]. Most fully developed are applications of SAR for sea/lake/river ice analysis and monitoring (denoted in Table 1 as "preoperational"). Three applications are the subject of the Alaska SAR Demonstration (denoted by "demonstration" in Table 1); i.e., winds, vessel detection, and storms. The remainder of this article will describe these products and the demonstration. Other applications listed in Table 1 are in a "research" status, actively being investigated for development into practical techniques for CoastWatch. If successful, these will be added to the demonstration as resources permit.

Alaska SAR Demonstration

Alaska SAR Demonstration Overview

A demonstration of near real-time SAR applications in Alaska began in the fall of 1999, with an anticipated duration of at least 2 years. The areas of interest are coastal Alaska waters of the Bering Sea, Beaufort Sea, Chukchi Sea, and Northern Gulf of Alaska (42° N - 76° N, 122° W – 155° E). Goals for the demonstration include: 1) Validate and test prototype SAR products that respond to critical needs not satisfied with present observational data in the Alaska region; 2) Provide SAR imagery and derived products in near real-time via the Internet for trial use by operational agencies; and 3) Familiarize operational agencies with SAR image data and products.

SAR Demonstration Users

Three major user groups are participating in the Alaska SAR Demonstration.

1) The primary users of wind and storm image products are the Anchorage, Juneau, and Fairbanks NOAA/ National Weather Service (NWS) Weather Service Forecast Offices (WSFOs) and the NWS Alaska Regional Office in Anchorage including the River Forecast Office and the Alaska CoastWatch Node. Collectively these offices have three marine forecasters who issue 25 coastal forecasts three times a day. Their region of responsibility includes 54% of the U.S. coastline. Their mission, although focusing on protection of life and property, also includes aiding the economic stability of the country. It is anticipated that SAR imagery and products will provide valuable coastal wind data to a region which has few *in situ* marine measurements (there are only four U.S. meteorological buoys in Alaskan waters, one in the Bering Sea, one in the Gulf of Alaska, and two in Prince William Sound, and four Coastal-Marine Automated Network (C-MAN) meteorological stations to serve 50,000 km of coastline). Alaska is a harsh environment for marine activities with ice hazards, severe storms, large waves, and dangers from superstructure icing. During the first three months of 1999, 11 people died and 14 more were seriously injured due to severe weather conditions encountered by the snow crab fishery in the Bering Sea. SAR data are already being used to provide ice information for Alaska waters by the National Ice Center and by the NWS forecasters in Alaska. In addition, the Alaska River Forecast Center has had three year's experience using SAR data for monitoring Alaska river ice breakup in the spring [3]. Besides providing additional wind observations, SAR imagery should provide unique and valuable information on storms at sea, particularly polar mesoscale cyclones (also known as polar lows or arctic hurricanes – see Fig. 2). These storms can arise suddenly and intensify to hurricane force winds with little or no warning from Alaska's sparse observation network [4]. In addition, overlying clouds often obscure these storms in conventional visible and infrared satellite cloud imagery. SAR data can provide unique, high resolution information on the morphology of the storm at the ocean surface including the location of the storm center and frontal regions.

2) The prime user for offshore vessel positions is the Coast Guard 17th District Office in Juneau, Alaska, which has responsibility for enforcing U.S. fishing regulations in U.S. waters, participating in enforcement of international agreements on the high seas, responding to oil spills, and rescuing those in peril at sea. Of particular interest to the Coast Guard are: a) the U.S./Russian Maritime Border region, ensuring that foreign fishing vessels are not trespassing into U.S. waters, b) the Steller sea lion rookeries in the Aleutian Islands and illegal fishing in restricted waters around the rookeries, and c) illegal driftnet fishing activities in international waters south of the Aleutian islands. With limited ship and aircraft resources and a vast region of responsibility, it is anticipated that SAR information on ship location and patterns of fishing activity will aid in the efficiency of search activities, in the monitoring of compliance when assets are not available in a particular region, and in the augmentation of legal case packages for prosecution of offenders. Imagery provided in preparation for the Alaska SAR Demonstration has shown vessel positions in relation to the U.S./Russian Maritime Border (see Fig. 3), and vessels

possibly engaged in illegal driftnetting (still to be confirmed). One question to be answered by the demonstration is the practicality of merging satellite-derived ship positions with ship ID and position information provided by the Vessel Monitoring System (VMS) scheduled for deployment during the next few years. This system will require vessels participating in particular fisheries, such as the Atka mackerel fishery, to have beacons on board which can be queried by the Coast Guard to monitor legal fishing activity. If queried at SAR satellite overpass times and paired with SAR-derived vessel positions, one should be able to tell if there are non-reporting vessels participating in the fishery (see the article by Montgomery elsewhere in this issue).

3) The prime user of coastal vessel positions is the Alaska Department of Fish and Game (ADFG) which has responsibility for managing fishing activities in Alaska coastal waters in order to provide for maximum sustained yield. An example of an important fishery managed by ADFG is the Pacific herring (*Clupea pallasii*) fishery for harvesting herring roe that occurs between late April and early June in coastal Alaska, particularly in Togiak Bay within Bristol Bay. Herring are caught with purse seines and gillnets. Also, roe sacks are harvested from kelp by divers. The herring and roe are transferred to Japanese tramp freighters which extract the roe and transport the catch to market in Japan. A highly regulated fishery, the herring roe season is sometimes only open for 15 minutes every few days. Standard mode SAR data from RADARSAT-1 and ERS-2 were used in Spring 1998 and 1999 to get a synoptic view of the herring roe fishery environmental conditions and vessel distribution.

Alaska SAR Demonstration Products and Algorithms

The initial demonstration system has three main products: (1) SAR imagery, (2) ocean vessel positions from SAR, and (3) ocean surface winds from SAR. Ancillary products are also provided to put the SAR imagery and derived products into the context of other available satellite, surface, and model environmental data (see Table 2). The primary source of SAR data is the Canadian RADARSAT-1 satellite carrying a C-band (5.6 cm) SAR with horizontal transmit and receive polarization. The most common data modes used in the demonstration are ScanSAR Wide B (450 km swath and 100-200 m resolution) and Standard (100 km swath and 25 m resolution). Occasionally, the ERS-2 SAR (vertical transmit and receive polarization) with its 100 km swath and 25 m resolution provides additional imagery when rapid repeat coverage is required.

SAR Imagery & Ancillary Products

During the Alaska SAR Demonstration, SAR image data are made available to users via an Internet-based image processing, analysis, and archiving system known as the WWW Image Processing Environment (WIPE) developed by Applied Coherent Technology Corporation (ACT Corp.). The WIPE system ingests near real-time SAR imagery and catalogues the data in a database for subsequent query by the end-user running an Internet browser on a personal computer (PC) or UNIX computer. The WIPE system also allows the user to download the SAR-derived products and ancillary data made available in the demonstration. WIPE allows the user to: browse the data; do image processing and analysis; create data cubes of collocated image, vector, and point data; and output/download data cubes or selected individual data sets. In this way, the

WIPE system also outputs all the products derived from the SAR data as well as any ancillary data entered into the WIPE system. Table 2 lists the initial products to be delivered by WIPE. The user requests data for a particular time period over a particular area. The coverage of available products is presented on a map for the user to select for downloading or display. Selected data are displayed as black and white or color images. Latitude and longitude grid lines, coastlines, bathymetry, and terrain elevations can be shown with the image. SAR imagery can be zoomed to full resolution and overlaid with derived product graphics or ancillary data. WIPE supports a number of input and output formats and can display data in polar stereographic or simple cylindrical projections. A user can choose to view/analyze the SAR data and products within the WIPE server itself or download data to his/her own computer/workstation for local analysis. WIPE can be programmed to deny access to SAR imagery while still allowing access to derived products for users that are not part of the U.S. Government or are not approved RADARSAT investigators. The SAR demonstration WIPE server resources allow up to four users to analyze data simultaneously on the server without serious degradation in response time. This constraint is consistent with the limited number of demonstration participants. Server resources can be expanded in the future as more users are added.

SAR-derived Ocean Surface Winds

Measurement of ocean surface winds from satellite scatterometer data is now quasi-operational. Routine availability of ERS-1/2 C-band scatterometer and the ADEOS Ku-band scatterometer data have fostered the development of mature algorithms for derivation of wind speed and direction from this type of data. But SAR instruments also have the potential for wind measurement. Like scatterometers, a SAR instrument measures variations in radar backscatter from the wind-roughened ocean, variations which are a function of wind speed and direction. Unlike scatterometers, SAR instruments only have one azimuth viewing angle, so wind direction must be obtained using a technique that differs from the multiple-azimuth measurement algorithm in use with modern scatterometers. An independent estimate of local wind direction, either from model output or from another source, is required for accurate wind measurement. Under the right conditions, wind-row patterns in the SAR data itself can be used to infer wind direction with 180 degree ambiguity [5]. SAR wind measurements have the advantage of being at very high spatial resolution (in the absence of noise, down to one pixel; i.e., 25-100 meters as opposed to the normal scatterometer resolution of 25-50 km) and can be made right up to the coast or in bays and estuaries without suffering from the land contamination evident in scatterometers and passive microwave radiometers. Two SAR wind products are being generated for the Alaska SAR Demonstration. Both products will be evaluated and compared as to their utility to operational weather forecast and analysis activities.

a. SAR Wind Images

An experimental procedure has been developed by The Johns Hopkins University Applied Physics Laboratory (JHU/APL) for estimating wind speed from RADARSAT ScanSAR Wide B and Standard mode SAR imagery. The data are first calibrated to units of radar cross section

using the calibration techniques provided by the Alaska SAR Facility (ASF) of the University of Alaska, Fairbanks, and then averaged to 1 kilometer pixels. A modified scatterometer wind algorithm is then used to relate radar cross section to wind speed. The algorithm employed is the C-band wind algorithm Model 4 (CMOD4), modified for the horizontal transmit, horizontal receive (HH) polarization of the RADARSAT SAR (see the articles by Thompson and Beal as well as Monaldo, this issue). Accurate wind estimates from this algorithm require knowledge of the wind direction, knowledge of the angle between the wind direction and the radar look direction, accurate normalized radar cross section measurements, and knowledge of the SAR incidence angle. In the preoperational wind procedure being developed, wind direction is obtained from a model wind analysis or forecast (on a 1 degree latitude/longitude grid), either from the Navy Fleet Numerical Meteorology and Oceanography Center (FNMOC) or the NOAA National Centers for Environmental Prediction (NCEP). Wind directions from the model gridpoint analyses are interpolated to the SAR image pixels and then SAR wind speed is calculated. The output is a high-resolution coastal wind speed map at 1 km resolution (see Fig. 4).

b. SAR Wind Vectors

A second wind product has been developed by ERIM International Inc. for the demonstration. In this algorithm, the wind direction is obtained from the SAR image itself when there are wind rows or other wind-aligned features in the SAR image. Fast Fourier transforms are performed on sections of the image, and the direction of the wind is determined from the peak in the spectrum or the smear of energy in the spectrum in the cross-wind direction [5]. The wind speed is determined with an algorithm similar to that used for the SAR wind images. Wind vectors over the ocean on a regular grid mesh with a spacing of approximately 32 km with 180° ambiguity in direction are the output of the algorithm.

Ocean Vessel Positions from SAR

Ships are often detected in visual examination of SAR imagery. They appear as bright targets with a contrast that depends on the background ocean backscatter. This contrast varies with wind speed, incidence angle, wave conditions, the presence of ocean features, and proximity to the coast. Because of the varying contrast, and the possibility that ocean features in some regions of an image can have a radar cross section as large as a ship return, a constant backscatter threshold often cannot be applied to the entire image to detect only ships. What is required is a point target detector. This classic signal processing problem is often solved using a Constant False Alarm Rate (CFAR) algorithm. A CFAR algorithm for ship detection has been developed by ERIM International Inc. and is being incorporated in the Alaska SAR Demonstration. The CFAR algorithm detects ships by first generating a local estimate of the probability density function (PDF) of the background ocean, then calculating a threshold such that there is a specified small probability (i.e., the false alarm rate) of finding a pixel above this threshold. Any pixel above the threshold is considered a ship. In practice, a large “background” data box (e.g., 19 X 19 pixels) is defined for determining the background statistics and a small “signal” box (e.g., 3 X 3 pixels) at the center of the background box is used to locate targets. The samples within a mid-size “background removal” box (e.g. 7 X 7 pixels) which is the size of the largest ship expected (also at the center of the background box) are not used when calculating the statistics of the background

box. The boxes are moved throughout the image to find all the ships. Since the local statistics are recalculated each time the boxes are moved, the threshold varies over the image. A land mask is employed to exclude land targets. Targets within 2 km of land are flagged since this region is susceptible to false alarms caused by satellite navigation errors or rocks, small islands, and mud flats not included in the land mask. Figure 5a is a small section of a RADARSAT ScanSAR Wide B image in the Bering Sea. There are fishing vessels in the image, most probably engaged in the Walleye Pollack trawl fishery. Dark regions behind the bright ship point targets are presumed to be slicks resulting from release of fish oils during the processing of the catch and release of by-catch [6]. Figure 5b is the output of the CFAR algorithm. A symbol has been added at the position of each detected ship to make it easier to see.

Anticipated Future Products

If all goes well with the launch of ESA's ENVISAT satellite in November 2000 and if these data can be processed at the ASF, then it is planned to add ENVISAT images to the Alaska SAR Demonstration in its second year. This will provide additional temporal coverage. Additional products which may be added in the second year of the demonstration include an ice mask, Quikscat scatterometer winds, and an ocean feature and oil spill map.

Demonstration Data Flow

Figure 6 summarizes the flow of data within the Alaska SAR Demonstration. The major data processing and communication activities are explained in this section.

1. SAR Data Reception and Image Processing

SAR data for the Alaska SAR Demonstration received at the Alaska SAR Facility (ASF) at the University of Alaska, Fairbanks are processed from satellite instrument data into SAR imagery in near real-time (3-6 hours). The images are then sent automatically via a dedicated T1 (1.544 Megabits per second) link to the National Environmental Satellite, Data, and Information Service (NESDIS) Satellite Active Archive (SAA) in Suitland, Maryland.

2. Satellite Active Archive

In the SAA, the data are catalogued, and then stored on-line for a week and in robotic tape storage for 3 years. After being catalogued in the SAA, the data are pushed automatically to (1) the NESDIS Office of Satellite Data Processing and Distribution (OSDPD) Sun Ultra 2 workstation in Camp Springs, Maryland, (2) the NESDIS Office of Research and Applications (ORA) Sun Ultra 2 workstation in Camp Springs, Maryland, and (3) the National Weather Service (NWS) Anchorage Weather Service Forecast Office (WSFO) Silicon Graphics Inc. (SGI) Indigo 2 workstation in Anchorage, Alaska. Data flows via a Fiber Distributed Data Interface (FDDI) network (at 100 Megabits per second) from Suitland to Camp Springs. There is a dedicated T1

link from Suitland to the NWS office in Anchorage.

3. Product Processing

In the OSDPD facilities, the data are stored in a large disk array (234 gigabytes) accessible to both the Sun Ultra 2 workstation and a PC running Windows NT. This disk array and a similar ORA disk array are both accessible by the OSDPD Sun, the ORA Sun, the OSDPD PC and the ORA PC. The OSDPD Sun runs the software to calculate products, storing them in the disk array for access by WIPE.

4. Product and Data User Access

Data are provided to the users via their web browser connected to WIPE running in the OSDPD PC. SAR data can be browsed and overlaid with products, or the products can simply be downloaded directly to the user's computer from the demonstration website.

5. Backup System and Validation.

ORA has a Sun Ultra 2 workstation, a disk array, and a PC identical to the OSDPD platform. This system will serve as a backup for the OSDPD machine and in addition hosts the ERIM International Inc. SAR tools software to be used for SAR algorithm development and testing. This machine will also be used for system development, testing, and validation work. During the demonstration, wind products will be matched with buoy and model winds to monitor and measure SAR wind algorithm performance. Target detection algorithm performance will be assessed by comparing output with known Coast Guard and commercial vessel positions, and eventually with known position of vessels participating in the Vessel Monitoring System.

Summery

This article has described the NOAA/NESDIS-sponsored Alaska SAR Demonstration which began in the fall of 1999, providing near real-time SAR-derived wind and vessel position products and SAR imagery to a small group of operational users in Alaska. SAR imagery and products are stored on a server and can be viewed over the Internet with a web browser. This two-year demonstration has the goal of providing routine preoperational SAR products in near real-time for evaluation and validation.

Acknowledgments

The sections describing the mission of the National Weather Service Alaska Region and the Coast Guard 17th District were taken from the presentations given, respectively, by Dr. Gary Hufford and Capt. Dennis Egan at the Johns Hopkins University Applied Physics Laboratory (JHU/APL) symposium on Emerging Coastal and Marine Applications of Wide Swath Synthetic Aperture Radar, March 23-25, 1999 in Laurel, Maryland. Figure 1 was provided by Kent Hughes of NOAA/NESDIS and the CoastWatch Program. Figures 2 and 3 were prepared by Karen Friedman of Caelum Corporation. Figure 4 was provided by Frank Monaldo of the JHU/APL. Figure 5 was provided by Chris Wackerman of ERIM International Incorporated.

The authors would like to thank those involved in developing the Alaska SAR Demonstration, specifically: Robert Beal, Francis Monaldo, and Donald Thompson of the JHU/APL; Christopher Wackerman, Robert Shuchman, and Michael True of ERIM International Inc.; Erick Malaret of Applied Coherent Technologies Corporation; Rick Guritz, Christopher Wyatt, and Verne Kaupp of the Alaska SAR Facility; Karen Friedman of Caelum Corporation; Xiaofeng Li of Research and Data Systems Corporation; William Tseng, Robert Stone, and Ralph Meiggs of NOAA/NESDIS; Don Montgomery of the Jet Propulsion Laboratory; Gary Hufford, Arleen Lunsford, Carven Scott, and Russel Page of the National Weather Service, Alaska Region; Capt. Dennis Egan and Cdr. Gregory Busch of the U.S. Coast Guard 17th District; and Fritz Funk and Katherine Rowell of the Alaska Department of Fish and Game. The SAR data system used to obtain SAR data for the demonstration was developed in partnership with the National Ice Center, including David Benner, Cheryl Bertoia and John Dowdell.

Funding for the Alaska SAR Demonstration and research preceding the demonstration was provided by the NOAA/NESDIS Ocean Remote Sensing Program. RADARSAT data were provided under the NASA RADARSAT Applications Development and Research Opportunity (ADRO) Project 396. Mention of a commercial entity or product does not constitute endorsement by the U.S. Government.

Biographies

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Table 1
SAR Applications of Interest to CoastWatch

SAR Applications of Interest to CoastWatch	
APPLICATION	STATUS in NOAA
<u>Coastal Oceanographic Applications</u> Coastal ice analysis and forecasting Vessel positions for fishery surveillance and management Ocean feature analysis (fronts, currents, river plumes, eddies, and upwelling) Identification of natural and man-made oil slicks Using internal wave measurements to measure mixed layer depth Detection and mapping of algal blooms Iceberg detection and tracking Wave measurements for maritime safety	Pre-operational Demonstration Development Development Research Research Potential Potential
<u>Hydrologic Applications</u> Analysis of river ice jams and associated flooding Lake ice analysis and forecasting Mapping coastal and river flooding Monitoring glacier-dammed lakes	Pre-operational Pre-operational Research Potential
<u>Meteorological Applications</u> Ocean surface wind measurements Winter storm and hurricane studies	Demonstration Demonstration
<u>Land Applications</u> Detection of coastline change Mapping wetland land use and change	Potential Potential

Table 2
ALASKA SAR DEMONSTRATION PRODUCTS

#	Product	Source	WIPE Data Display	Download Format (External to WIPE)
1	<u>SAR IMAGERY</u> a. RADARSAT SAR Imagery	ASF/SAA	B/W Image	Available from the SAA
2	b. ERS-2 SAR Imagery	ASF/SAA	B/W Image	Available from the SAA
3	<u>ANCILLARY DATA</u> a. GOES Vis & IR Imagery	NESDIS	B/W Image	Available from other sources
4	b. ERS-2 Scatterometer Wind Vectors	NESDIS	Color Wind Barbs	Text File, GIF image
5	c. SSM/I Wind Speed	NESDIS	Color Image	Text File, GIF image
6	d. 14 km SST Analysis	NESDIS	Color Image	Lat/long flat file, GIF image
7	e. Buoy Observations (Winds, SWH, Air Temp., SST, Air Pressure)	NDBC	Location, time, and values	Text file
8	f. Model Analysis and Forecast Output (Winds, SWH, Air Temp., SST, Air Pressure, Dominant Wave Period and Direction)	NCEP/ FNMOC	Color image for all parameters, also color wind barbs for winds	GRIB file, GIF image
9	g. Model Air-Sea Temp. Diff. Analysis and Forecast	JHU/APL	Color image	GIF image
10	h. Model Inverse Wave Age Analysis & Forecast	JHU/APL	Color image	GIF image
11	<u>SAR DERIVED PRODUCTS</u> a. Vessel Positions	ERIM	Symbols	Text File
12	b. Winds from SAR (Vectors with 180 deg. ambiguity)	ERIM	Color Wind Barbs	Text File,
13	c. SAR Wind Image	JHU/APL	Color image	NetCDF file, Meta data file, Validation file, GIF image

Acronym Definitions for Table 2:

ASF = Alaska SAR Facility

B/W = Black and White

CEOS = Committee on Earth Observing Satellites

ERIM = Environmental Research Institute of Michigan International Inc.

FNMOCC = Fleet Numerical Meteorology and Oceanography Center

GIF = Graphics Interchange Format

GOES = Geostationary Operational Environmental Satellite

GRIB = Gridded Binary

IR = Infrared

JHU/APL = The Johns Hopkins University Applied Physics Laboratory

NCEP = National Centers for Environmental Prediction

NDBC = NOAA Data Buoy Center

NESDIS = National Environmental Satellite, Data, and Information Service

NetCDF = Network Common Data Form

SAA = Satellite Active Archive

SSM/I = Special Sensor Microwave/Imager

SST = Sea Surface Temperature

SWH = Significant Wave Height

WIPE = WWW Interactive Processing Environment

Figure Legends

Figure 1 - CoastWatch Nodes

Location of the Central CoastWatch Node (Suitland, MD) and the eight Regional Nodes

Figure 2 - Polar Mesoscale Cyclones

Two polar mesoscale cyclones as imaged by the ScanSAR Wide B mode of the RADARSAT SAR. Both of these storms are located in the same region of the Bering Sea, but are separated in time by 48 days (North is to the lower right corner).

Figure 3a - Radarsat ScanSAR Wide B Image Covering the U.S./Russia Maritime Border.

ScanSAR Wide B image from July 5, 1999 at 0542 GMT in the vicinity of Cape Navarin Russia in the Bering Sea. The image includes the U.S./Russia Maritime Border. The area for Figure 3b is shown by the white rectangle.

Figure 3b -Ships Aligned with U.S./Russia Maritime Border

Enlargement of a portion of Figure 3a. The white dots (high backscatter) are ships engaged in the walleye pollack fishery in the Bering Sea in Russian waters. The U.S./Russia Maritime border is shown. This image shows numerous ships lined up along the border, fishing close to U.S. waters.

Figure 4 - SAR Wind Image

Wind calculated from a SAR image using the CMOD4 algorithm and an HH/VV polarization ratio. The arrows are the model wind directions.

Figure 5a - Section of SAR Image in Bering Sea

Image shows vessels engaged in the Walleye Pollack fishery, with dark areas of water calmed by release of fish oils during processing of the catch. This is a RADARSAT ScanSAR Wide B image.

Figure 5b - Ships Detected in Figure 5a

Ships detected in Figure 5a are shown by circled dots.

Figure 6 - Alaska SAR Demonstration Data Flow

The flow of data planned for the Alaska SAR Demonstration.

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